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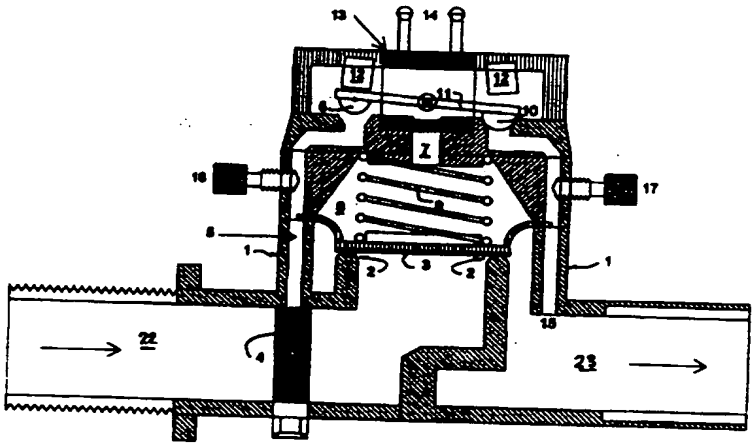
(54) Title: SOLENOID ACTUATED BI-STABLE PILOT VALVE



(57) Abstract

A solenoid actuated bi-stable pilot valve comprises a rockable yoke (11) of magnetic material surrounded by a coil (13) to form an electromagnet. The yoke has rubber valve members (6, 10) at opposite ends which close respective valve orifices, alternately. Like-poled permanent magnets (12) interact with the yoke electromagnet poles to cause the yoke to rock from one position to the other to thereby control operation of a main fluid control valve in the form of a diaphragm valve. In another form (Fig. 3) two similar pilot valves control a main diaphragm valve whereby the main valve may be set to a fully open or closed position or any position therebetween such that the flow rate may be controlled. In order to achieve a greater force to close the pilot valves a polarized magnetic circuit as shown in Figure 3A incorporates a lever (38) to actuate the yoke attached perpendicularly to the yoke at its pivot point. A toilet cistern (20) incorporating main flow control valves with pilot valves according to the invention is also disclosed. The cistern operates electrically by low power replaceable batteries and is controlled by a microcontroller (32) and push button switches (34, 35) and has a low battery warning light and fault signal for cleaning inlet filters. Also disclosed is a float incorporating a magnet which, using the "Hall Effect", sends electronic signals to the microprocessor for empty, half full and full conditions.

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TITLE: SOLENOID ACTUATED BI-STABLE PILOT VALVE

This invention relates to a solenoid valve and more particularly to a solenoid actuated, bistable, pilot valve and to a fluid control valve incorporating same. In addition the invention relates to a toilet cistern incorporating a solenoid actuated fluid control valve.

Electrical solenoid valves are well known and are often used as pilot valves for the purpose of controlling operation of larger fluid control valves. The known valves have a sliding armature and either a spring or a permanent magnet for influencing the movement or positioning of the armature. Examples of such solenoid valves may be found in U.K. patent specification 1,419,262; 1,417,669 and 2,076,117 as well as U.S. patent specification 4,505,450, for example. Whilst many of the known solenoid valves are designed to utilize small control signals or small amounts of power and whilst the bistable valves disclosed in the aforementioned U.K. specification 1,419,262 and 1,417,669 only require a low power electrical pulse for operation from one state to the other, the amount of power consumed is still significant. Furthermore known solenoid actuated fluid control valves, such as diaphragm valves, have only two conditions, namely, 'on' or 'off' and are not controllable to any position therebetween.

Accordingly it is one object of the present invention to provide a solenoid actuated pilot bistable valve which operates on extremely low power facilitating battery operation over an extended period of time.

A further problem which the present invention is intended to address is in the art of toilet cisterns where conventionally a float is used to control a high pressure water inlet valve to refill the cistern and a somewhat complex mechanism is used to open the low pressure outlet valve for the purpose of flushing the toilet. The internal complexities of construction of the known cisterns is increased with the advent of dual flush cisterns wherein two different water compartments and/or two different outlet valve actuating arrangements are necessary. This greatly increases the cost of manufacture of conventional cisterns and limits the shape of

the cistern tank.

Also, conventional toilet cisterns are noisy during the refilling operation essentially because the inlet valve employed has a small high pressure orifice due to the fact that it must be operated by a relatively low force provided by the float with limited moment arm.

Accordingly it is a further object of the present invention to provide an improved toilet cistern which overcomes or at least reduces the aforementioned problems of known toilet cisterns.

The invention therefore provides a solenoid actuated bi–stable pilot valve, characterised in that, said valve comprises a rockable yoke having respective ends adapted to close respective valve orifices alternately, said yoke is electromagnetically actuated to rock between a first position wherein one valve orifice is closed and the other orifice is open, and a second position wherein said one valve orifice is open and said other valve orifice is closed, and said yoke is held in each alternate position by a permanent magnet.

The invention further provides a fluid control valve incorporating two pilot valves as defined in the preceding paragraph whereby the fluid control valve may be set to a fully open or closed position as well as any position therebetween.

A still further form of the invention provides a toilet cistern wherein the main fluid control valves are each controlled by a pilot valve as defined hereinabove.

In order that the invention may be more readily understood particular embodiments will now be described with reference to the accompanying drawings wherein;

Fig. 1 is a schematic sectional side elevation of a diaphragm valve incorporating a solenoid actuated pilot valve in accordance with the invention;

Fig. 2 is similar to Fig. 1 but shows a low pressure form of the diaphragm valve;

Fig. 3 is a view similar to Figs. 1 and 2 of dual solenoid actuated pilot valves according to a further embodiment of the invention;

Fig. 3A shows a modified form of the dual solenoid actuated pilot valves of Fig. 3; and

Fig. 4 is a schematic sectional front view of a toilet cistern in accordance with the invention.

The various embodiments all depict a main diaphragm valve which employs a solenoid actuated pilot valve or a pair of solenoid actuated pilot valves for controlling operation of the diaphragm. By reversing the polarity of an applied digital pulse, the diaphragm valve (main valve) is caused to open or close, or in the case of the Figure 3 embodiment may be set to a position between open and closed.

Figs. 1, 2 & 3 depict solenoid actuated pilot valves for operating diaphragm valves. Figures 1 and 3 employ a spring loaded diaphragm and depict mains pressure versions. Figure 2 utilises a lightly spring–loaded bellows and is intended for low pressure applications.

The diaphragm valve of Figures 1 and 2 comprises a main body component 1, with main valve seat 2 and diaphragm 3 shown in the closed position. Pressurized fluid applied to the inlet 22 (Fig. 1) causes an upward force on the underside of the diaphragm 3 which is balanced by an equal and opposite force created by the fluid which passes through the filter 4 via the duct 5, through the pilot valve 6 and duct 7 to the diaphragm chamber 8 and hence to the top side of the main diaphragm. A helical spring 9 (or lightly spring–loaded bellows 9 as in Fig. 2) keeps the main valve closed against pressure surges.

The solenoid actuated pilot comprises the synthetic rubber valves 6 & 10 which are mounted on the yoke 11 which is made from a rustproof, soft magnetic alloy and which pivots about the fulcrum to alternately close the pilot valve orifices. The valves are maintained in a closed position, alternately, by the like–poled ferrite permanent magnets 12 which are attached to the plastic housing so that, for example, their north poles are projecting from the plastic housing. A solenoid coil 13 of insulated wire is positioned around the long axis of the yoke 11, with its ends terminated at 14.

In operation, a brief, low power DC, single pulse is applied to the solenoid terminals 14 with the result that the yoke is momentarily magnetised such that one end becomes a north pole and the other end a south pole. The north pole end will be instantly repelled by the adjacent permanent magnet and the south pole end will

be attracted and held by its adjacent permanent magnet, hence one of the valve orifices will be closed. If the polarity of the applied DC pulse is reversed, the whole action is reversed and the alternate valve is closed and the first opened.

Referring again to Figure 1, it will be appreciated that if the state of the pilot valve is changed the valve 6 is closed and the valve 10 opened, hence the pressure on the top side of the main diaphragm is released and fluid from the diaphragm chamber 8 will flow via ducts 7 and 15 to the outlet 23 (or to atmosphere in Fig. 2). Continuing flow creates a venturi effect on the end of duct 15 hence the pressure in the diaphragm chamber 8 remains low and fluid continues to flow through the main valve until the state of the pilot valves is again changed. The screws 16 and 17 alter the fluid flow through the ducts 5 and 15 respectively and hence they may be adjusted to set the rate of operation of the opening and closing action. In commercial production where the valve is manufactured for a specific purpose, the screws may be omitted and the duct bore optimised for the particular application.

Figure 3 is a diagrammatic representation of a more complex version of the solenoid valve of figure 1 which, in addition to the basic features, has the facility to control the rate of flow. A very low cost microcontroller circuit (not shown) is used to control four pilot valves. This embodiment comprises two identical solenoid valves arranged side by side and referenced 18 and 19, respectively. The components of each valve have like reference numerals.

As depicted, the main valve is turned off because both pilot valves 10 are closed. This is because pressurized fluid at inlet 22 enters the diaphragm chamber 8 via duct 5, intermediate chamber 37 and duct 7 to provide equal pressure on both side of the diaphragm 3. If reversing pulses are applied to the respective solenoid coils 13 both pilot valves 6 are then closed and the pilot valves 10 are opened. This causes the main valve to open and fluid flows as described in relation to the earlier figures.

If, however, at an appropriate instant after the opening state has been initiated and the diaphragm is lifting, a further pulse is applied to solenoid valve 19 and hence pilot valve 10 thereof is closed, then the intermediate chamber 37 and

diaphragm chamber 8 are effectively sealed and the main valve is stopped in a partially open state. Conversely, if the valve is in the process of closing with pilot valves 10 closed, and a pulse is applied to solenoid 18, then pilot valves 6 of the solenoid valve 18 will be close and the main valve will again be set in a partially closed state.

Thus, by employing appropriate timing or incorporating a position or flow transducer, (not shown) the main valve can be controlled to provide an infinitely variable range of flows from fully on to fully off.

Furthermore, by incorporating two or more of these devices, preferably in the one body unit with the addition of input and output temperature sensing (not shown), a variable mix, variable flow unit can be constructed for a variety of applications.

Because the moving component of the pilot valves are of low mass construction and do not employ biasing springs, they require very little power to change their state. In a typical domestic application where a pair of valves are combined to control flow and temperature for a shower or hand basin, an electronic microcontroller circuit powered by two AA cells could be expected to operate for approximately two years before battery replacement would be required.

By utilising appropriate materials in the construction of the units, they may be used to control the flow of a variety of fluids of appropriate viscosity.

Fig. 3A shows a modification to the solenoids 18 and 19 of the dual pilot valve arrangement shown in Figure 3. According to the modification the yoke 11 in each case is provided with a rigid actuating lever 38 which is fixed to the yoke 11 (or formed integral therewith) at the mid-point or pivot point of the yoke. The lever 38, in each case, is surrounded by a polarized magnetic circuit comprising solenoid coil 39 and permanent magnets 40 40'. The lever 38 and polarized magnetic circuit facilitate a greater force to close the pilot valves 6 and 10 in situations where there is a high water pressure.

In each magnetic circuit the adjacent poles of the opposed magnets 10, 10' are of opposite polarity as shown, for example, in Figure 3A. Energizing the coil 39 magnetises the lever 38 which is formed of magnetic alloy such that the end of

the lever 38 adjacent one set of opposed permanent magnet poles becomes, say, a north pole and the other end a south pole. The lever is thus attracted to one side or the other depending upon the polarity of the pulse applied to the coil 39 via terminals 14. Such action occurs at both ends of the lever 38 and thus, a considerable force is applied to the lever 38 and hence the yoke 11. Reversal to the digital pulse causes the lever 38 to move in the opposite direction and in either case the lever is retained in position, until application of a reverse pulse, by the permanent magnets. Clearly the polarized magnetic circuit arrangement of the dual pilot valve embodiment could be applied to the single pilot valve embodiment of Figures 1 and 2.

Figure 4 is a diagrammatic representation of a toilet cistern or tank incorporating the valves described in figures 1 and 2.

A cistern 20 is filled from the mains supply by water passing through the inlet valve 21, the fill pipe 25 and silencer/syphon-break cap 24. As the water level rises, the float 26, which includes a magnetic plastic ring 27, mounted around its internal inner circumference, follows and is captively guided to rise and fall with the water level, by the over-flow pipe 28.

Hall-effect magnetic sensors 29, and 30 detect the presence of the float magnet to identify the full and empty states of the cistern. Sensor 31 is adjustable and is provided to detect the nominal half-full position. The sensors are electrically connected to microcontroller assembly 32 by leads (not shown) for controlling operation of the valves. The overflow pipe 28 is mounted integrally with the outlet valve 32 which is connected to the toilet pan (not shown).

Item 33 is a small watertight compartment containing the batteries (not shown) which may be 2 x AA cells, and microcontroller electronic assembly 32 together with the initiating push buttons 34 for part flush and 35 for full flush. Pilot light 36 flashes slowly when the batteries need replacement and in short bursts when a fault condition occurs such as the need to clean the filter(s). Although this event is dependent on the purity of the local water supply, it is a task of the microcontroller to periodically sample the time taken for a flush cycle which is compared with a reference record and notified if required. The microcontroller is

programmed to manage all of the functions of the operation, maintenance and fault conditions likely to be experienced.

Trials and estimates have indicated that battery life is expected to be 3 to 5 years when the system is used in typical domestic situations.

It should be evident that the present invention provides an improved bistable solenoid operated pilot valve which can be actuated between states by an extremely low power pulse and therefore provides considerable advantage over the prior art. The low power operation is achieved by the low mass of the yoke 11, the rocking action thereof which, opposed to a sliding action requires less power to move, and the attraction/repulsion between the electromagnet and the permanent magnets. The toilet cistern according to the invention provides simple, low cost, electrically actuated pilot valves with solid state logic to reliably provide all of the modern functions using a minimum number of components. Not only is the cost of manufacture rationalised but the traditional noise of the filling function is virtually eliminated and there are no 'washers' to replace. Because the mechanical restriction imposed by the traditional float valve has been eliminated, the cistern can be produced in a variety of shapes to suit any particular installation ranging from fully featured to concealed. It is also worth mentioning that the problem of water hammer which occurs with some existing solenoid actuated diaphragm valves and float controlled valves may be avoided with the present invention due to the controlled rate of closure of the diaphragm.

CLAIMS:

1. A solenoid actuated bi-stable pilot valve, characterised in that, said valve comprises a rockable yoke having respective ends adapted to close respective valve orifices alternately, said yoke is electromagnetically actuated to rock between a first position wherein one valve orifice is closed and the other orifice is open, and a second position wherein said one valve orifice is open and said other valve orifice is closed, and said yoke is held in each alternate position by a permanent magnet.

2. A valve according to claim 1, characterised in that, said electromagnetic actuation is by a single electric pulse.

3. A valve according to claim 2, characterised in that, said yoke is formed of magnetic material and forms an electromagnet with poles at opposite ends and said permanent magnet for holding said yoke in each alternate position comprises permanent magnets of like pole arranged adjacent the respective ends of said yoke whereby attraction between an end of the yoke and an adjacent one of said permanent magnets holds said yoke in said first position or said second position depending upon the polarity of said electromagnet and said permanent magnets.

4. A valve according to claim 2 wherein said valve is incorporated into the housing of a main fluid control valve, characterised in that, a coil surrounds said yoke and is electrically energised to provide an electromagnetic field, said coil is switchable between opposite polarities to reverse the poles of said yoke thereby causing said yoke to rock from said first to said second position, or vice versa, by magnetic attraction between one end of the yoke and the adjacent permanent magnet, and magnetic repulsion between the other end of the yoke and the permanent magnet adjacent thereto.

5. A valve according to any one of the preceding claims, characterised in that, said yoke is pivotally mounted mid-way between its ends.

6. A valve according to claim 2, characterised in that, said yoke has a lever rigidly affixed thereto and extending therefrom and a polarized magnetic circuit encompasses said lever to electromagnetically actuate said yoke.

7. A valve according to claim 6, characterised in that, said lever is

attached to the yoke at a point mid–way between the ends of the yoke, at which point the yoke is pivotally mounted.

8. A fluid control valve including a solenoid actuated pilot valve for controlling operation of a main valve, characterised in that, two pilot valves as defined in claim 1 are used in combination to control operation of the main valve whereby the main valve may be set to a fully open or closed position as well as any position therebetween.

9. A fluid control valve according to claim 8 wherein said main valve is a diaphragm valve, characterised in that, a first of said pilot valves controls a first valve orifice between a high pressure inlet duct of the main valve and an intermediate chamber, and a second valve orifice between said intermediate chamber and diaphragm chamber; and the other of said pilot valves controls a third valve orifice between said diaphragm chamber and said intermediate chamber and a fourth valve orifice between said intermediate chamber and a low pressure outlet duct of the main valve.

10. A fluid control valve according to claim 9, characterised in that, said pilot valves are actuated by a single electric pulse to switch from one position to the other.

11. A fluid control valve according to claim 10, characterised in that, the yoke of each pilot valve has a lever rigidly affixed thereto and extending therefrom and a polarized magnetic circuit encompasses said lever to electromagnetically actuate said yoke.

12. A fluid control valve according to claim 11, characterised in that, each said lever is attached to the yoke at a point mid–way between the ends of the yoke, at which point the yoke is pivotally mounted.

13. A fluid control valve according to claim 10, characterised in that, said yoke of each pilot valve is formed of magnetic material and forms an electromagnet with poles at opposite ends, and said permanent magnet for holding said yoke in each alternate position comprises permanent magnets of like pole arranged adjacent the respective ends of said yoke whereby attraction between an end of the yoke and an adjacent one of said permanent magnets holds said yoke in said first position or

said second position depending upon the polarity of said electromagnet and said permanent magnets.

14. A toilet cistern including a high pressure inlet fluid control valve and a low pressure outlet fluid control valve, characterised in that, each valve is controlled by a pilot valve as defined in claim 1.

15. A toilet cistern according to claim 14, characterised in that, said inlet and outlet valves are diaphragm valves and opening and closing of said inlet valve and closing of said outlet valve is electrically controlled by float means and opening of said outlet valve is electrically controlled by a first switch.

16. A toilet cistern according to claim 15, characterised in that, said float means comprises an annular float surrounding a vertical overflow pipe in said cistern and said float has a magnetic ring mounted around the internal circumference thereof, and Hall-effect magnetic sensors are provided on said overflow pipe at differing heights to identify full and empty states of said cistern, said sensors being electrically connected to a microcontroller for controlling operation of the valves.

17. A toilet cistern according to claim 16, characterised in that, a further Hall-effect magnetic sensor is provided on said overflow pipe between said full and empty state sensors to identify a part empty state of said cistern whereby said outlet valve is closed when a nominal half flush condition is initiated by a second switch.

18. A toilet cistern according to claim 17, characterised in that, said switches are push button switches or proximity switches.

19. A toilet cistern according to claim 18, characterised in that, electrical power to operate said cistern is provided by a low power replaceable battery and operation, maintenance and fault control is managed by said microcontroller which is programmable.

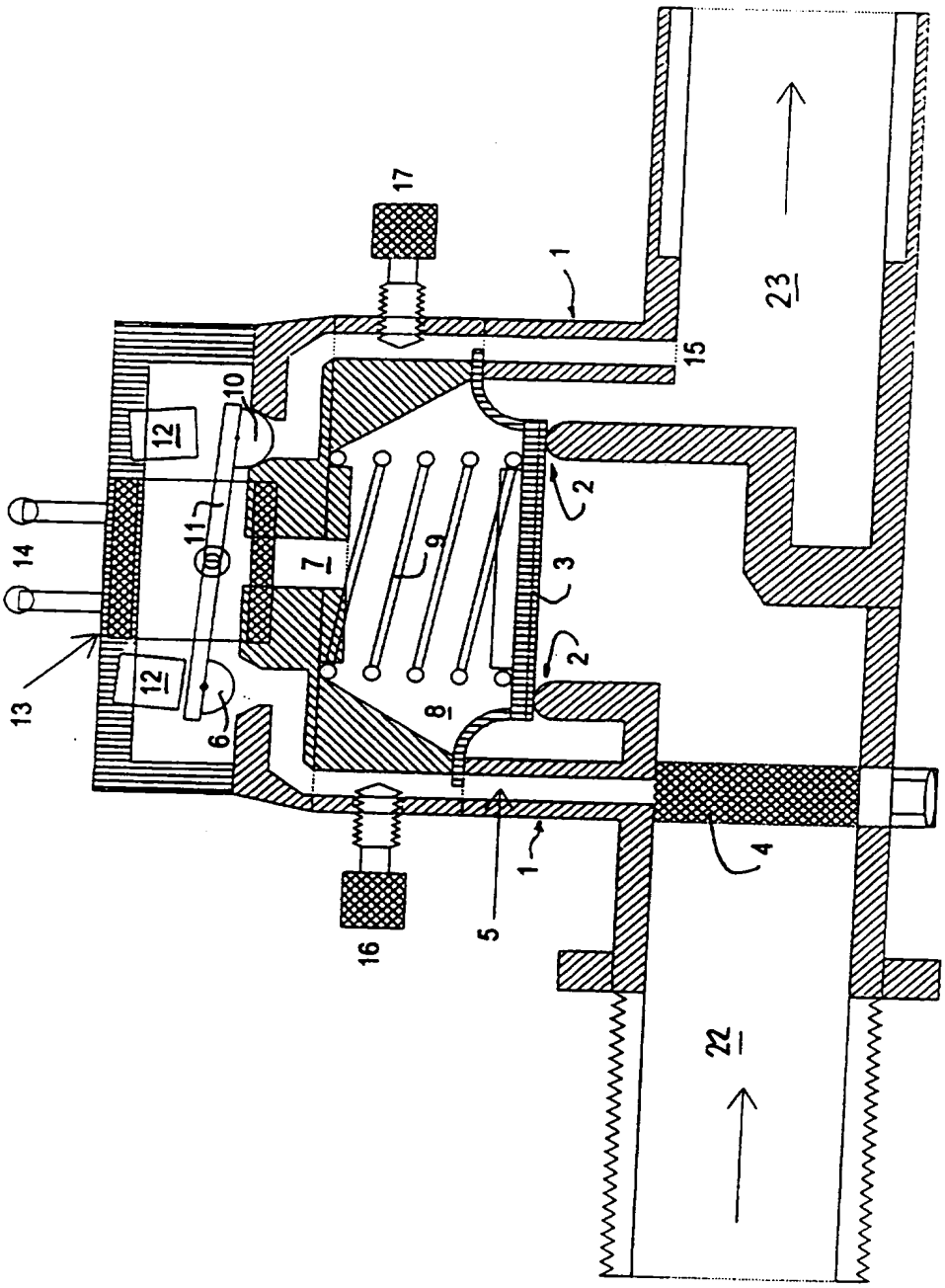

FIG. 1

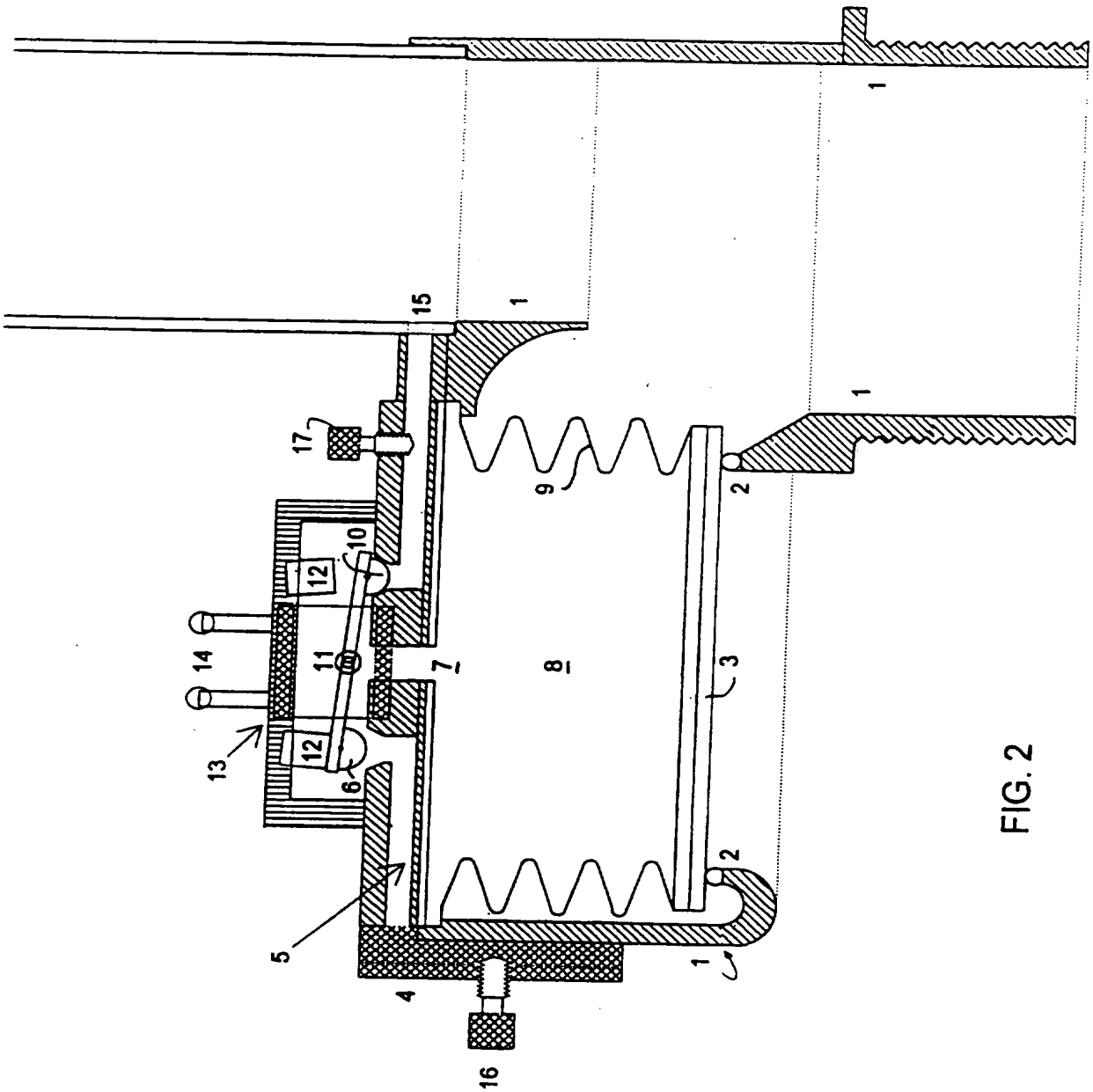

FIG. 2

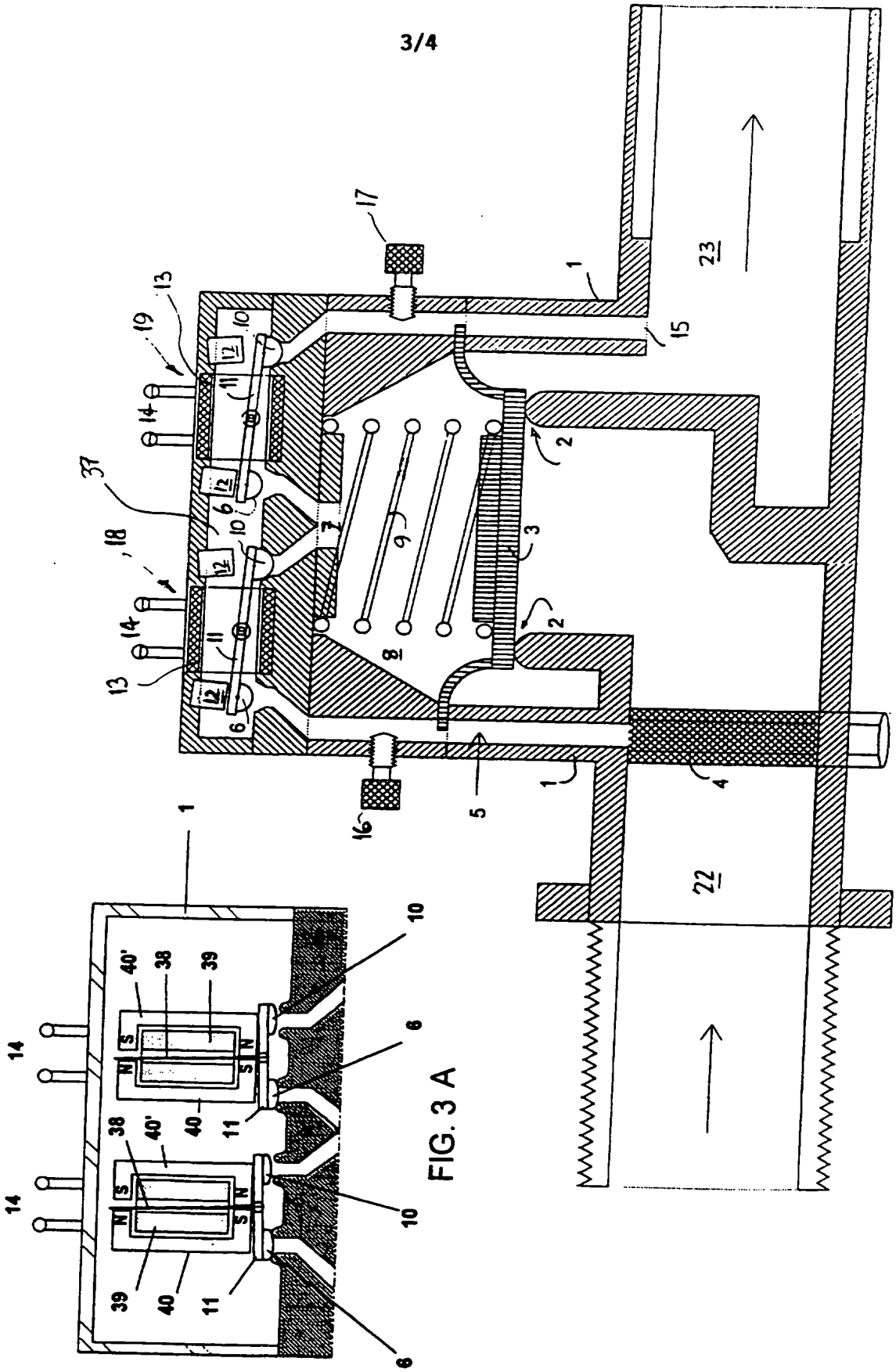

FIG. 3

FIG. 3 A

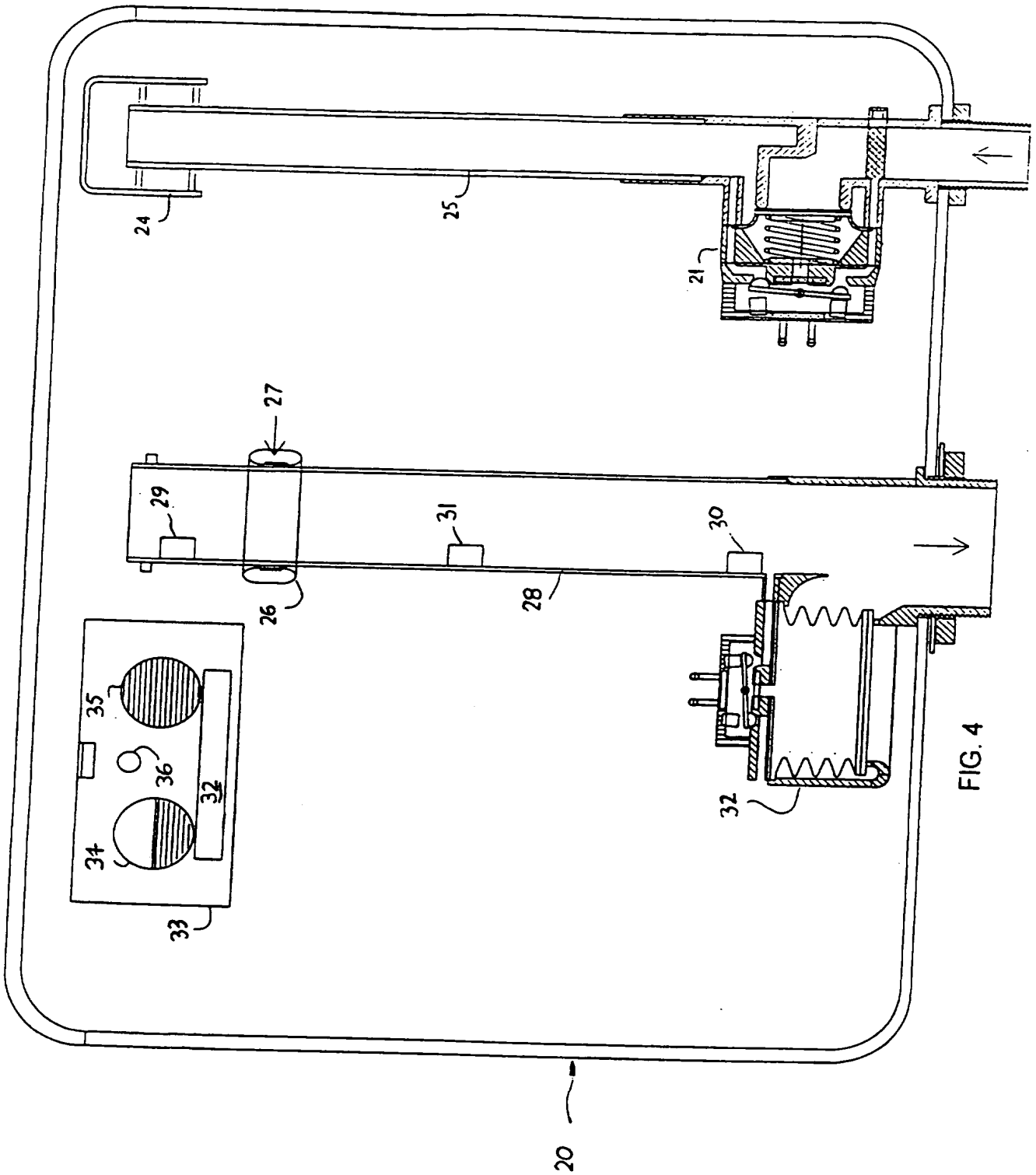

FIG. 4

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/AU 95/00666

A. CLASSIFICATION OF SUBJECT MATTER

Int Cl[6]: F16K 31/08, 31/34, 31/40, 31/56, 33/00, E03D 1/32, 1/33, 1/34

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F16K 31/08, 31/40, 31/56, E03D 1/32, 1/34, 1/35

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU:IPC as above, F16K 31/10, 31/11, 31/18, 31/20, 31/34, 33/00

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
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DERWENT : (F16K 31/18 OR 31/20 OR 31/34 OR 33/00) AND Magnet :

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	AU 50538/79 A (BAXTER TRAVENOL LAB. INC.) 21 August 1980 Whole document	1, 2, 5
X Y	GB 1348671 A (BÜRKERT) 20 March 1974 Fig. 5, page 3 lines 36 to 50 "	1, 2, 5, 8
X Y	US 5226627 A (HESS et al) 13 July 1993 Whole document "	1, 2, 5 8

[X] Further documents are listed in the continuation of Box C

[X] See patent family annex

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9 January 1996	19.01.1996
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INTERNATIONAL SEARCH REPORT

International Application No.
PCT/AU 95/00666

C (Continuation) **DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	US 3532121 A (STURMAN et al) 6 October 1970	
X	Whole document	1, 2, 5-7
Y	"	8
	US 4343329 A (TURANSKY et al) 10 August 1982	
X	Whole document	1, 2, 5-7
Y	"	8
	EP 343288 A (KOPPENS AUTOMATIC FABRIEKEN B. V.) 29 November 1989	
Y	Whole document	8
	GB 2119481 A (AIDA ENGINEERING LTD) 16 November 1983	
A	Whole document	1-19

INTERNATIONAL SEARCH REPORT
Information on patent family members

International Application No.
PCT/AU 95/00666

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
AU	50538/79	BE	881622	CA	1118820	DE	2934712
		ES	484336	GB	2044005	IL	58115
		JP	55107207	US	4236132	ZA	7904534
GB	1348671	DE	2037774	FR	2103773	GB	1348671
US	5226627	JP	5215267	DE	4139958		
US	3532121						
US	4343329	US	4428188				
EP	343288	AT	77683	DE	3872385	ES	2032950
		US	5042775				
GB	2119481	DE	3307215	FR	2526117	IT	1153620
		JP	59001888	SE	5817/82		

END OF ANNEX